tures, so vital in the propagation of the Tillamook fire, were also big factors in the spread of these other large fires. Then, too, there were no organized agencies in those days for the prevention and suppression of forest fires, so it is likely they became much larger than would be possible under the efficient present-day methods for prevention and suppression. The weather in the northern Coast Range from August 21 to 26, particularly on the 25th and 26th, when the greatest damage was done in the Tillamook fire, was extremely bad and most likely as bad as any that had ever previously existed. Except for this one bad fire and the Wolf Creek fire, the protective organizations of Oregon and the Pacific Northwest enjoyed one of the best seasons in the history of organized protection in 1933.

TABLE 1.—*Highest daily wind velocity recorded at certain stations in northwestern Oregon during the 2 critical fire-weather periods in August 1933*

Stations	10th	11th	12th	13th	14th	15th	16th	21st	22d	23d	24th	25th	26th
North Head, Wash.[1]	28	27	26	26	22	20	17	18	20	15	16	17	18
Baker Point	12	17	20	15	23	16	6	16	25	10	14	30	28
Mount Hebo	11	14	24	20	20	14	10	24	25	13	14	28	20
Prairie Mountain	12	13	24	18	18	5	10	20	22	10	6	25	10
Portland [1]	11	13	15	15	13	11	9	15	17	8	10	19	16
Highland Butte	6	8	8	12	10	15	6	20	24	8	10	34	20
Green Peter	10	13	13	17	7	13	10	21	26	10	10	30	27
Mount Wilson [2]	16	20	21	20	19	23	19	36	39	22	34	43	31
Crown Point [3]	8	10	8	8	9	24	8	26	24	23	18	39	32

[1] Maximum wind during day, midnight to midnight, for period of 5 minutes.
[2] Highest average hourly velocity for day, midnight to midinight.
[3] 5 a.m. to 1 a.m.
Records at other sations are for daytime only, ranging from 6 or 7 a m. to 7 or 8 p.m.

TABLE 2.—*Departure of daily lowest relative humidities of 2-hour duration from the mean for August at the fire-weather stations nearest the Tillamook fire during the period the fire was most active in August 1933, also number of hours the relative humidity was below 35 percent for each of the 2 periods at each station*

	Mean	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th	21st	22d	23d	24th	25th	26th	27th	Number of hours, 35 percent, and lower	
																				10–16	21–26
VALLEY STATIONS																					
Youngs River	56	0	−3	−14	−12	−27	−17	−9	......	+2	+2	−5	−33	−35	−18	−8	−36	−29	+16	6	32
Jewell	50	−7	−7	−17	−20	−26	−22	−11	−11	−2	−5	−7	−28	−33	−33	−25	−34	−33	+26	18	47
Oregon-American	52	−18	−19	−22	−22	−28	−31	−12	−11	+3	+13	−5	......	......	......	......	......	......	......	28	......
Vernonia	44	−9	−11	−14	−15	−19	−25	−5	−1	+5	+14	−8	−19	−27	−24	−16	−27	−27	+24	29	52
Clark and Wilson	46	−6	−10	−11	−11	−17	−29	−9	−5	−4	+9	−10	−23	−28	−23	−19	−26	−26	+18	18	56
Forest Grove	40	−9	−12	−14	−17	−18	−17	−12	+7	0	+9	−7	−17	−18	+1	−11	−19	−18	+25	48	49
Portland	44	−9	−1	−12	−7	−8	−15	0	+15	+12	+6	+1	−9	−23	−20	−7	−25	−25	+23	14	52
Herman Creek R.S	41	+8	+1	+4	+6	+3	−23	−8	+5	+5	+5	+6	−13	−18	−19	−21	−19	−20	+6	11	51
HIGH RIDGE STATIONS																					
Tidewater Tbr. Co.	53	−8	−10	−18	−17	−29	−23	−9	−6	+2	+5	−6	−33	−33	−30	−23	−29	−28	+24	15	69
C. H. Wheeler	48	−15	−18	−16	−17	−22	−23	−5	−3	+3	+15	−8	−23	−28	−28	−15	−22	−20	+23	38	88
Brix Logging Co	51	−9	−10	−12	−14	−17	−25	+4	−19	+18	+8	+11	−23	−28	−23	−16	−26	−27	+15	10	83
Mount Hebo Lookout	58	−19	−11	−13	−23	−35	−32	−23	−28	+20	+24	+5	−31	−36	−35	−23	−33	−37	+2	87	136
Black Rock Camp	47	−4	−12	−14	−16	−19	−11	−15	−7	+3	+3	−11	−17	−22	−17	−11	−17	−19	+11	36	65
Green Peter Lookout	49	−22	−26	−40	−29	−30	−33	−23	−6	−3	+21	−3	−25	−34	−29	−19	−35	−27	−1	66	114
Mount Wilson Lookout	42	−13	−21	−24	−22	−21	−20	−22	−12	+5	+42	+18	−8	−11	−19	−10	−7	−8	−19	120	32
COAST STATIONS																					
Nehalem	64	−7	−15	−11	−10	−17	−5	+4	−6	+4	−3	−17	−51	−48	+8	+17	+8	−9	+18	7	20
Hebo	62	+10	+2	+1	+5	−12	−5	+3	+8	+6	−7	−9	−24	−40	+20	+13	−32	+4	+14	2	23

LONG-PERIOD FLUCTUATIONS OF SOME METEOROLOGICAL ELEMENTS IN RELATION TO CALIFORNIA FOREST-FIRE PROBLEMS

By LESLIE G. GRAY

[Weather Bureau Office, San Francisco, Calif., June 1934]

Weather is a very important factor in the starting and spreading of forest fires (1) (2) (3). Each weather element affects fire behavior in different ways of varying importance. At present, the forester takes advantage of short-period daily, day-to-day, and seasonal weather changes in carrying on his work of fire prevention and suppression, and is further aided by short-range forecasts by meteorologists. However, the forester is handicapped in planning a long-period forest protection policy, budgets, and administration by lack of foreknowledge of long-period weather sequences—ignorance as to what to expect from trends of given types and to what extent long-period fluctuations in specific weather factors have affected or will affect his fire problems. The purpose of this paper is to present in a preliminary way the facts obtained by an extensive compilation of California data, and to note the inferences drawn by various students of weather sequences, expressed in terms of the forester's fire problem. It should be emphasized here that this discussion deals with recorded data, and indicates furture prospects only to the extent that we may justifiably assume that the "before" and "after" pictures will be the same or similar.

The various weather factors are expressed as mean values for the State of California, using for each item a homogeneous body of data from selected stations. For comparison purposes, other hydrological and related data, mostly from other than Weather Bureau sources, are used as supporting evidence. The principal graphical method used for presenting the data is that of accumulated departures from normal or average, or residual mass curves, the computation and meaning of which are explained by Barnes (4) and Marvin (5). Briefly, accumulated departures are well adapted for showing secular sequences, trends, or changes without distortion of the actual data. The method accomplishes natural smoothing without obscuring the real values. Where the graph shows a rise, values have been above average; where it shows a fall, values have been below average; and where it is horizontal, values have been exactly average. E. H. Bowie visualizes accumulated departures as representing a sort of bank account between the State of California and nature.

Nature makes deposits to the credit of California, which are drawn against naturally and by human use, the accumulated departure curve at any time showing the existing bank balance. During a series of exactly normal precipitation years, for example, there are no departures, and the graph is the single horizontal zero plotting or normal line. In a series of supernormal years, however, deposits are heavier than withdrawals, and the balance increases. In subnormal years, withdrawals exceed deposits, and the balance to California's credit is reduced.

Figure 1 shows mean precipitation values for California, adjusted to a 100-station standard. The 100 stations are geographically well-distributed, and in numbers proportional to the percentage of the total State area within given elevation zones, as follows: Low level, less than 500 feet, 21 stations; foothill level, 500 to 2,500 feet, 34; intermediate level, 2,500 to 5,000 feet, 23; high level, over 5,000 feet, 22.

Records are practically complete for the period 1911–30 for all of the 100 stations. Means for the different elevation zones during these 20 years show minute qualitative

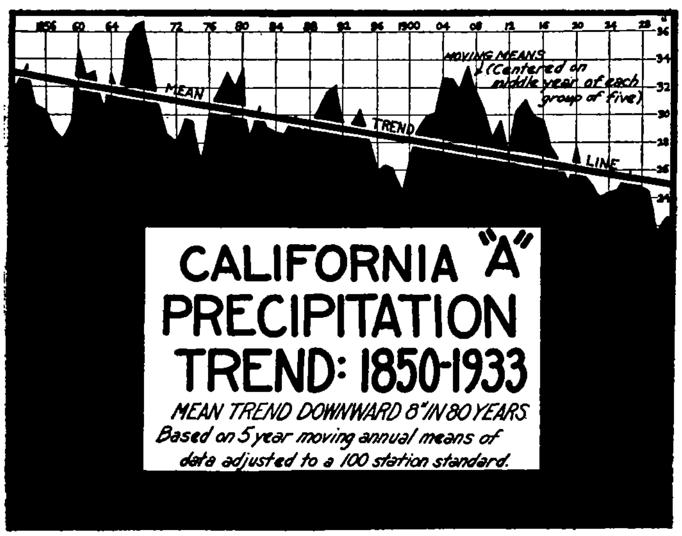

FIGURE 2a.

agreement from month to month, differing only quantitatively, since the higher zones have the larger means. Percentage relations between various combinations of stations and the 100-station mean for this period, worked out by months, were used to reduce the records for the varying number of stations extending back to 1850, to the 100-station standard. The final means are believed to represent practically a reliable and homogeneous body of data, giving approximately true relative precipitation differences from year to year, although not representing, necessarily, the real total amount of precipitation over the entire State area.

The actual mean seasonal precipitation (July–June) since 1850–51 in figure 1 shows an apparent downward trend. The next graph shows departures from average, and clearly brings out the decreasing variability of California precipitation as the seasonal means decrease. The next section shows accumulated departures, illustrating the long-period sequences or swings in series of dry and wet years, not readily perceptible from the other graphs. In general, California received more than its 84-year normal rainfall up to 1890. Then there were short downward and upward trends, and, finally, a steady decrease since 1916, the decrease being much faster than the original accumulation. The lower section, giving moving 5-year annual means, illustrates the long-period downward trend in the annual mean. Similar moving means of sunspot numbers show no clear-cut relationships.

Figure 2 deals further with precipitation. Section "A" shows the downward trend in annual means more clearly by exaggerated scale, the trend being of secular nature and amounting to about 8 inches in 80 years, or at a rate of about 0.10 inches per year. Section "B" shows single and double curved trend lines fitting the data somewhat more closely. Analysis of possible cycles is not within the scope of this paper, but it may be pointed out that successive harmonics of the trends would result in a series which, added algebraically, would correspond with the original curve.

Streiff (**6**) mentions that Marvin found 24 possible harmonic elements in precipitation data, Baur 20 in temperature and Michelson 33 in sunspot numbers. The multiplicity of cycles, periodicities, and sequences apparently discovered in various data by many investigators has led to doubts in some quarters as to the reality of definite periods. Some regard apparent regular cycles as fortuitous. Others recognize numerous influences at work which, conceivably, may be related to apparent complex harmonies. This view holds that some alleged periods are not fundamental, but represent reinforcements or interferences of cycles of varying length or amplitude or both. The effect is a series of more or less irregular waves in the plotted crude data.

However, in section "A", a definite symmetry of values with reference to the mean trend line is observable about the year 1886. Notice the close qualitative correspondence between the various peaks and depressions extending both ways from 1886. Details are shown in section "B." With some differences of 1 or 2 years in the number to right and left of the year of symmetry, possibly due to displacements caused by the moving means method employed, details of the comparable numbered peaks and depressions of section "B" appear in table "C" It is a singular fact that the mean year of symmetry agrees *exactly* when calculated separately from maxima and minima. Barnes (**4**) found an identical year of symmetry for English rainfall, describing his findings in the following words: "The balance about a certain center is particularly noticeable . . . the center at first sight appearing to occur at the end of 1884 if *short* equal periods are taken on either side . . . But . . . dry years subsequent to that date were more in number than wet years preceding it . . . hence, for *long* periods the center becomes displaced to the end of 1886." His data were plotted in terms of accumulated departures, and not directly, as for the California data.

Investigating the matter further, a 203-year rainfall record for selected English stations compiled by Alter (**7**) was plotted in chart "D" by moving 5-year means, Barnes' data were included and the California data added. The curves apparently indicate a very perfect symmetry of English rainfall around 1829, from 1803 to 1856, in the actual data, 26 and 27 years on each side of 1829, respectively. The data also show symmetry in terms of *accumulated departures* about the years 1886 and 1772, the first well-marked and extending from 1856 to 1916, and the other rather imperfect, and extending from about 1741 to 1803. California data show direct value symmetry about the year 1886. The data seem to show wave interference phenomena already mentioned. If extended symmetries actually occur, they form a ready means of projecting sequences ahead, given sufficient

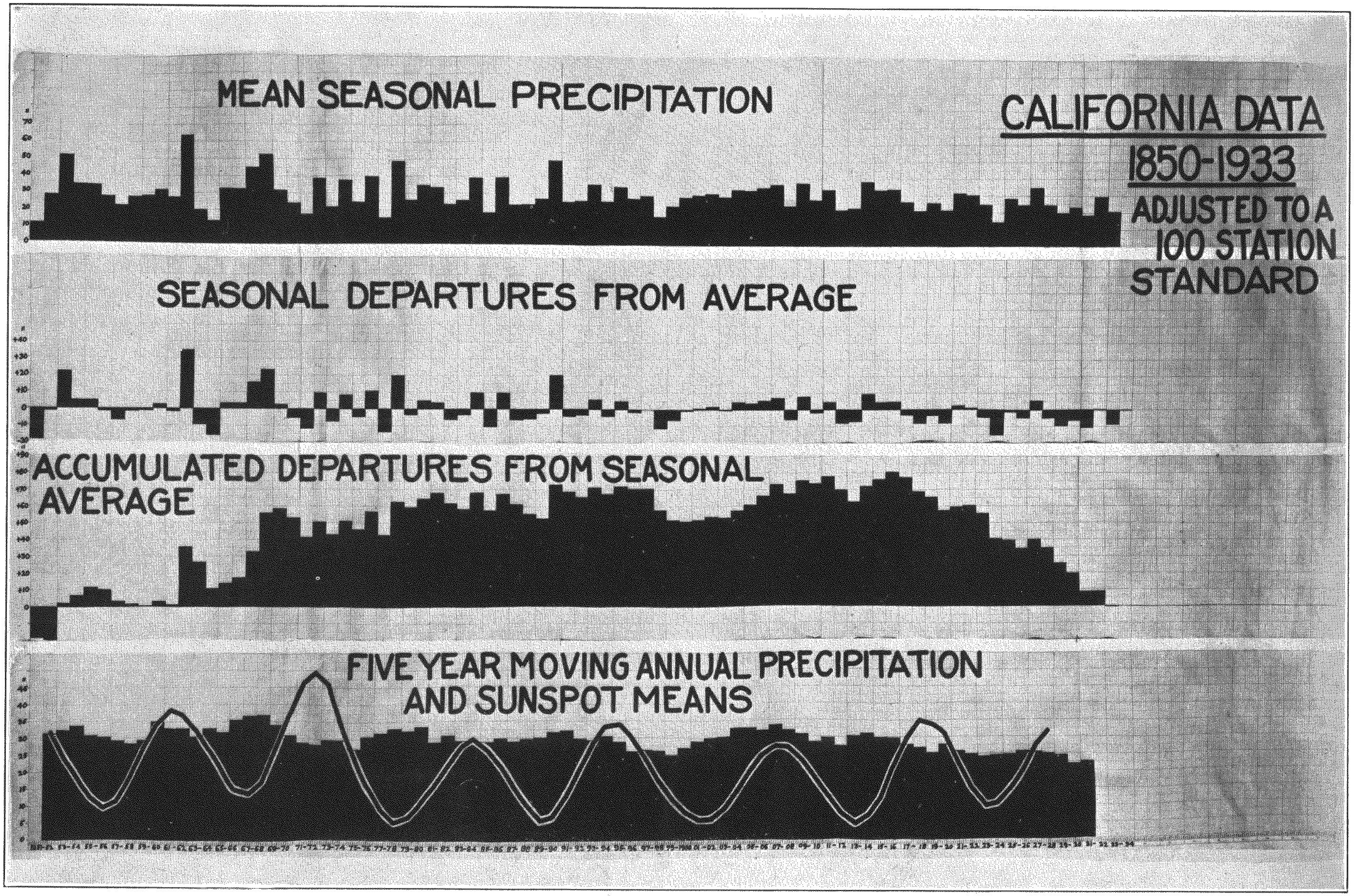
MEAN SEASONAL PRECIPITATION
CALIFORNIA DATA
1850-1933
ADJUSTED TO A
100 STATION
STANDARD
SEASONAL DEPARTURES FROM AVERAGE
ACCUMULATED DEPARTURES FROM SEASONAL
AVERAGE
FIVE YEAR MOVING ANNUAL PRECIPITATION
AND SUNSPOT MEANS

FIGURE 1.

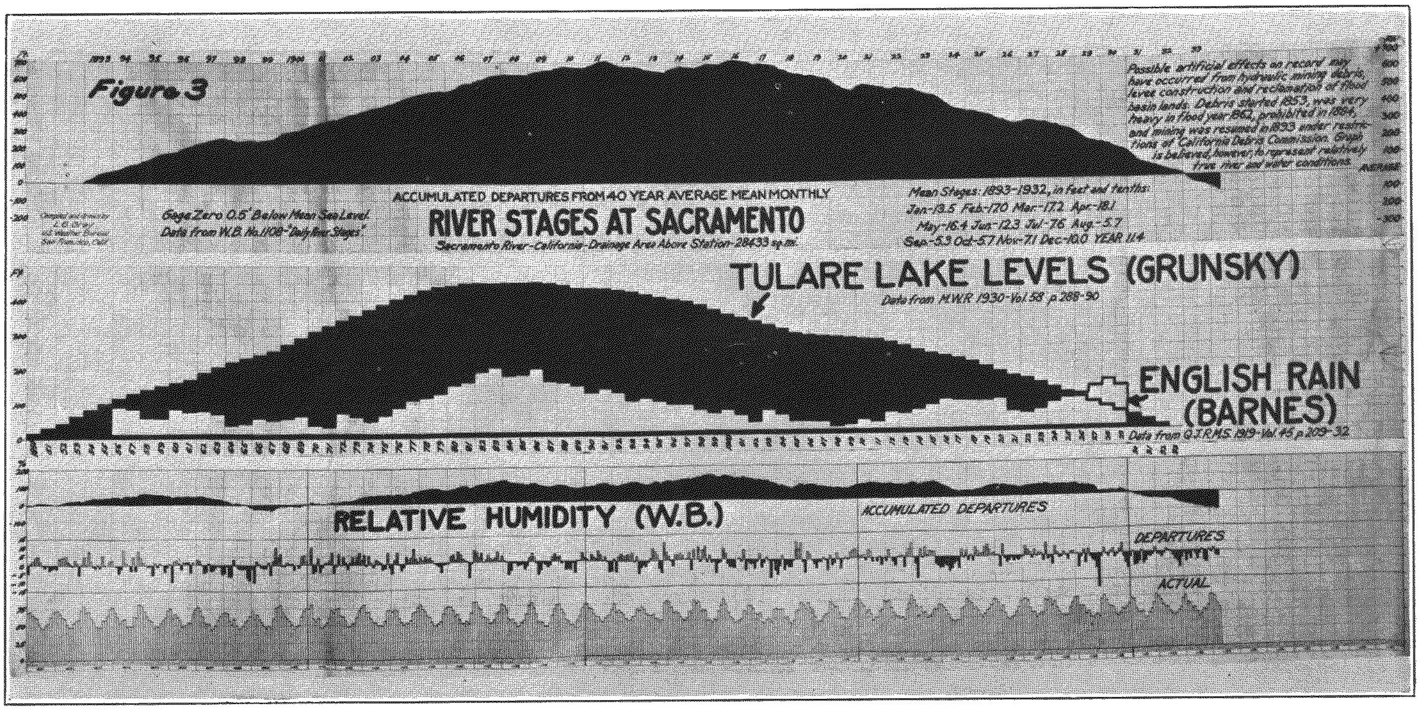

FIGURE 3.

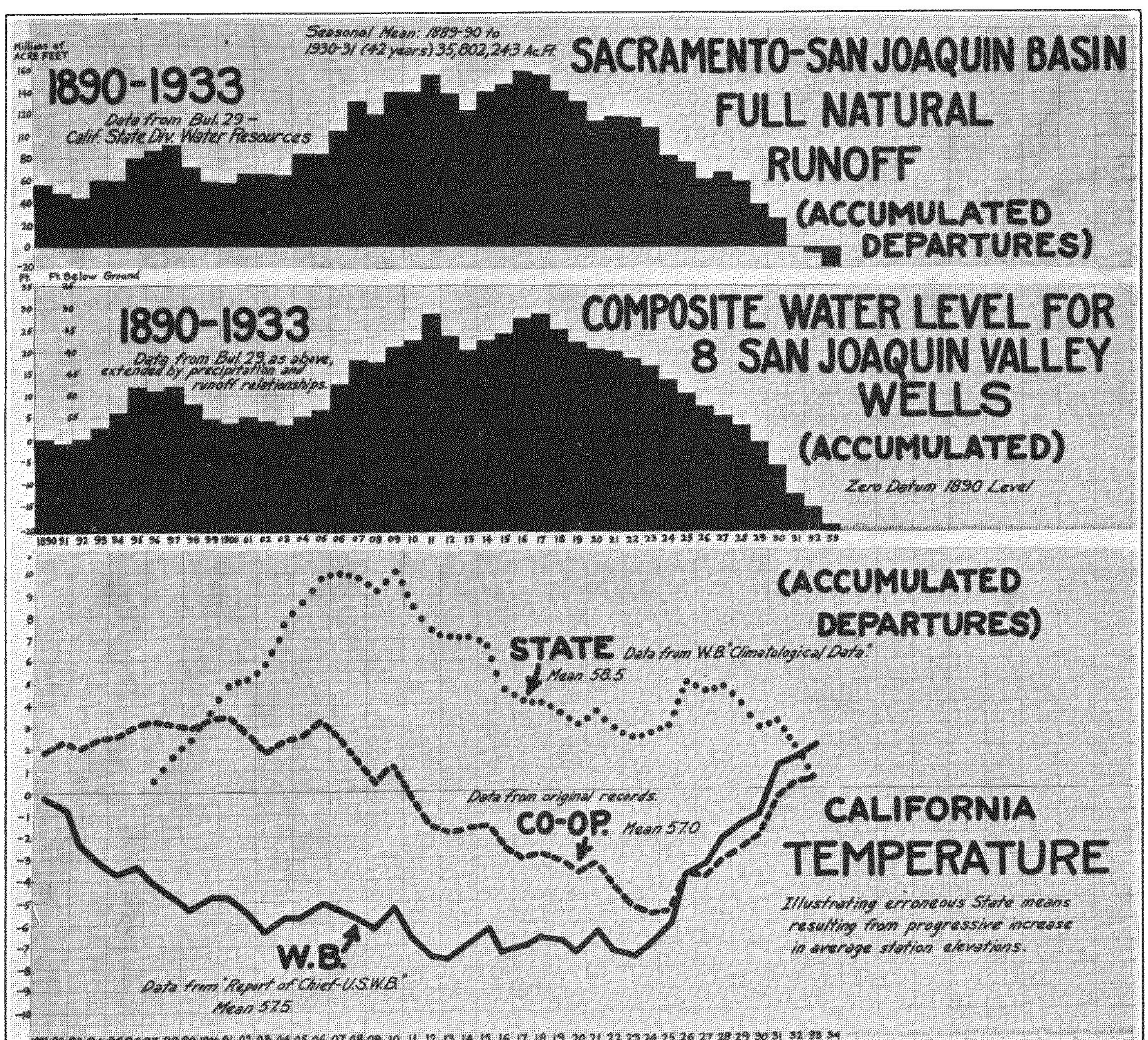

FIGURE 4.

back data, and eliminate the labor and difficulties involved in disentangling fundamental periods. A symmetry of precipitation about the year 1903 has been found for Algeria. Recent German investigations have shown pronounced symmetries of barometric pressure for short periods. Further study of precipitation symmetry is warranted, even though definite use of symmetries in anticipating future conditions is not yet, and may not be, possible.

Figure 3 presents hydrological data confirming the downward trend in precipitation already mentioned. River stages at Sacramento show a peak in 1916 and a steady subsequent decline, supporting the precipitation peak of 1916. Tulare Lake levels show a maximum in 1886, agreeing with the English rainfall data, given below for comparison. The lower section shows weighted relative humidity means for 11 Weather Bureau stations,

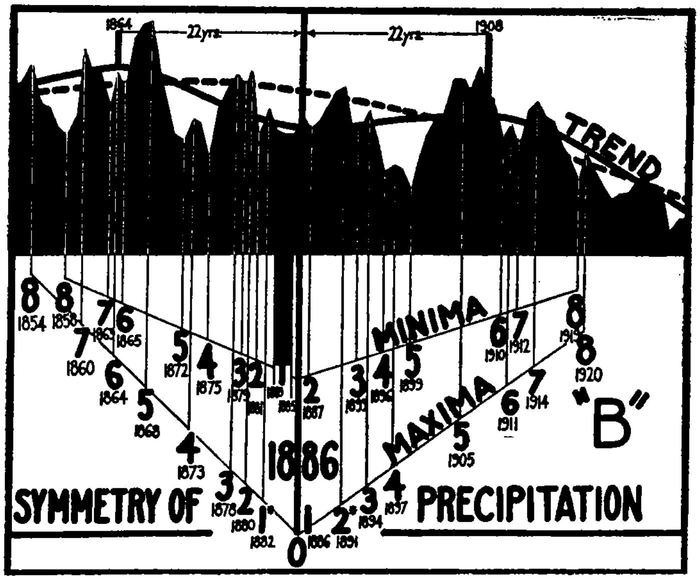

FIGURE 2b.

by months, since 1891, comparing the different methods of presentation and showing a confirming downward trend since about 1915. Figure 4 shows full natural run-off from the Sacramento-San Joaquin drainage basin, confirming the precipitation data in terms of downward trend since 1916. Similarly, water levels in wells in the San Joaquin Valley have dropped rapidly since 1917, the difference amounting to 48 feet in 18 years. The steep rate of decrease is due, apparently, to the excessive drain on stored underground waters by pumping made necessary by the current series of dry years.

State means of temperature were plotted in the lower portion of the figure, but show discordant results, which are connected with the progressive increase in elevation of stations used in determining the mean. The 11 Weather Bureau stations used for relative humidity show more consistent results. To further check the temperature trend, 11 cooperative stations were selected, and their combined trend agrees satisfactorily with the Weather Bureau stations, although trending upward during the first 10 years. Temperature has been below average from 1891 to 1923, and has since been above average with a much steeper cumulative trend.

Figure 5 shows all weather elements plotted simultaneously, so far as possible using the record for the period 1900–33. Vapor pressures show downward trend in general since 1914; temperature a marked upward trend since 1923; and evaporation, being a net result of several influences, is erratic, but on the whole trends upward since 1923. Snowfall data show a downward trend since 1923, and snow depths April 1 show an even more marked drop, beginning with 1922. Thunderstorm days show a fairly regular downward trend since 1918, and lightning fires a marked upward trend since 1922, leveling off in 1925. In this case, the greater liability to fire-start due to decreasing precipitation and consequent forest fuel dryness about balances the lesser chance for lightning fires due to decreasing numbers of thunderstorm days. Wind velocity, adjusted to an uncorrected 4-cup anemometer basis, appears to show a more or less regular 22 year sequence, although the record is too short to be certain. The regularity is hard to explain as accidental.

	MINIMA		"C"	
		MEAN MID-YEAR		
1	1883	1884.0	1885	2
2	1881	1884.0	1887	6
3	1879	1886.0	1893	14
4	1875	1885.5	1896	21
5	1872	1885.5	1899	27
6	1865	1887.5	1910	45
7	1863	1887.5	1912	49
8	1858	1888.5	1919	61
No.	Year	1886.06	Year	Yrs.
	MAXIMA			
1	1882	1884.0	1886	4
2	1880	1885.5	1891	11
3	1878	1886.0	1894	16
4	1873	1885.0	1897	24
5	1868	1886.5	1905	37
6	1864	1887.5	1911	47
7	1860	1887.0	1914	54
8	1854	1887.0	1920	66
No.	Year	1886.06	Year	Yrs.

FIGURE 2c.

Fortunately for fire protection, wind velocity has trended downward during the bad fire years since 1924. Wind velocity shows a very close relation to fire areas, the total burned acreage decreasing to 1916 with about normal wind and supernormal precipitation, but increasing as the wind increased thereafter to and including 1924, when the rate of increase was accelerated by increasingly subnormal precipitation and high temperatures. The leveling off of the burned acreage trend after 1926 seems to be due primarily to decreasing wind movement, since the precipitation and temperature trends continued to be unfavorable, although temperature leveled off somewhat in 1931 and later. The percentage of sunshine for the 11 Weather Bureau stations has increased since 1916, bears a nearly perfect inverse relationship to the number of cloudy and rainy days, and all three agree remarkably well with the precipitation trends. Relative humidity has trended downward since 1922 and agrees in general features with the precipitation.

From regional summarizations furnished by the United States Forest Service, data computed and plotted in the lower portion show that forest fires in the national forests of California decreased from 1908 to 1912, and then increased at a fairly steady rate, in a cumulative sense, until 1925, when the number leveled off. This is true both of lightning and man-caused fires. Total burned acreage decreased from 1908 to 1916, trended slightly upward to 1923, and then steeply upward to 1925, after which it leveled off. Apparent improvements in protection organization and technique seem to be shown by the trends of average burned area per fire, which has trended downward somewhat in recent years in spite of more unfavorable conditions, and at a more rapid rate than either number or total area of fires. Suppression costs and damage to forest values parallel one another, and show rather smooth downward trends to 1923, upward trends to 1931, and a leveling off thereafter. The snowfall accumulation is plotted for comparison, and shows a fairly good inverse relationship to costs. Temperature, however, shows practically a direct relationship in all particulars to the trend of costs. Snowfall seems

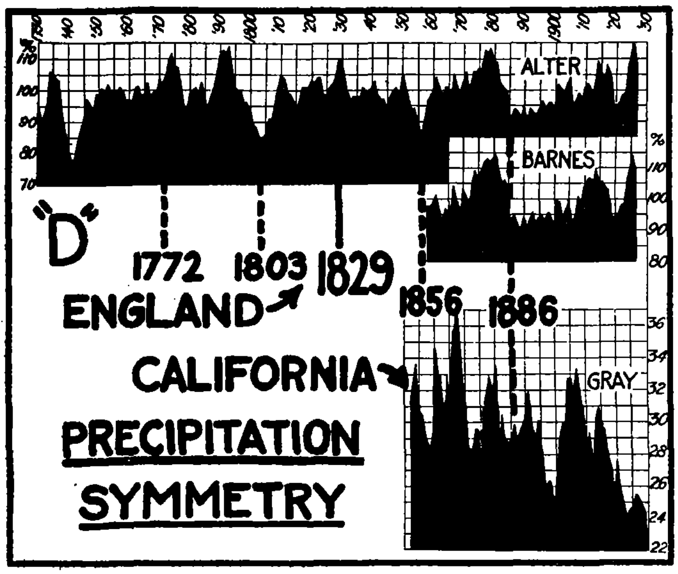

FIGURE 2d.

to be a combining factor, integrating the effects of both temperature and precipitation.

It is believed that the foregoing has demonstrated the truth of the following statements:

1. Long-period weather sequences occur in California, in numerous individual meteorological and hydrological factors or elements.
2. Long-period fluctuations are apparent also in forest-fire data.
3. The weather trends are responsible, primarily, for fluctuations of fire numbers, areas, and costs, and are important not only over short periods, as is generally recognized, but also over long periods, including those of secular nature. The precipitation trend is the single one most closely connected with all others.
4. All trends, in general, have been toward more unfavorable conditions for fire prevention and suppression, especially since 1916 for some elements, and since 1923 for practically all others.
5. The accumulated departure method employed in this paper appears to more effectively bring out secular trends, and clearly shows the importance in California forest-fire problems of cumulative as opposed to temporary influences.

With reference to our current position in terms of long time weather sequences, and future prospects, I shall summarize the opinions of several authorities and students of cyclic phenomena, for what they may be worth. Streiff (**6**) believes that about 1940–50 the precipitation may have again increased about 30 percent to values prevailing around 1880. He has determined a secular sunspot cycle apparently similar to the precipitation sequence, and supports it with precipitation data for the eastern and western United States, and Sequoia tree ring data. In another article (**8**), he points out that the Brückner cycle minimum occurred in 1929, and that a maximum is due around 1939. The longer secular cycle, he thinks, should reach a maximum around 1945–50. A previous minimum of this cycle occurred in 1905 and a maximum in 1875. Previous lengths of the secular cycle have been 70, 60, and 90 years, an average of 73 years. During the Brückner cycle minima, dry and warm years are frequent, and during maxima, wet and cool years predominate. He emphasizes the lack of applicability of his data to short-term forecasting of momentary changes, as is usually required of practical meteorology, and the direct applicability to long-period forecasting of cumulative changes, of great importance in hydrology and engineering. It has been shown in my paper that the long changes of cumulative nature in California are important in forest fire problems, and hence there is an analogy to hydrology in the long-time policy or planning sense. Shuman (**9**) agrees with Streiff, and gives data showing river discharges in Michigan with maxima in 1935 and 1939, and with minima in 1931 and 1937, but with a moderate general upward trend after 1931.

According to Shuman and Streiff, the long secular cycle in weather elements had a maximum about 1851 and a minimum about 1907. The sunspot secular cycle had maxima in 1780 and 1856, and will again be high about 1950. Minima occurred in 1816 and 1906. Streiff emphasizes that the crest of the Brückner cycle on each side of the peak of the secular cycle is higher than usual, with the implication that the peak of the Brückner cycle prior to about 1950, and the one after that date, will have greater amplitude than usual. Shuman indicates that the Brückner and secular cycles will trend upward, in general, until about 1950–52. The present drought situation over a considerable portion of at least the Northern Hemisphere in middle latitudes, from his data, appears to be the result of coincidence of several cycles which happen to reach minimum or near-minimum values simultaneously. From correlations of Lake Ontario levels, he finds that levels will decrease to about 1934–5, and increase up to 1940, with the values for 1930–50 a little lower than for 1870–90.

Clough (**11**) believes that a series of mild winters are due about 1940, based on the combined effects of a Brückner cycle of 37 years (Streiff thinks the true Brückner cycle is 22.6 years) and an 83-year period. Based on a 275- to 300-year period, he believes that a warm and dry epoch will occur around 2000. Based on a 1,400-year period, he says:

> Evidently . . . in 75 or 80 years from now (2050?), or the second recurrence of the Brückner period, the near-coincidence of minimum phases of four periods will occur and as a result there are likely to be prolonged and disastrous droughts.
>
> The exceptional warmth and dryness of the past few years can only be explained as the result of the near-coincidence of the 37-year and 83-year epochs of minima, combined with the effect due to the relatively near approach of the longer periods. Of course, the Brückner period has the largest amplitude so that around 1950 or 1955 the weather will be considerably cooler and wetter than at present. However, it is probable that the present century as a whole will prove to be exceptionally dry and warm as compared with the past two centuries.

If the foregoing summarized statements are valid and if the internal evidence of California data, which are in

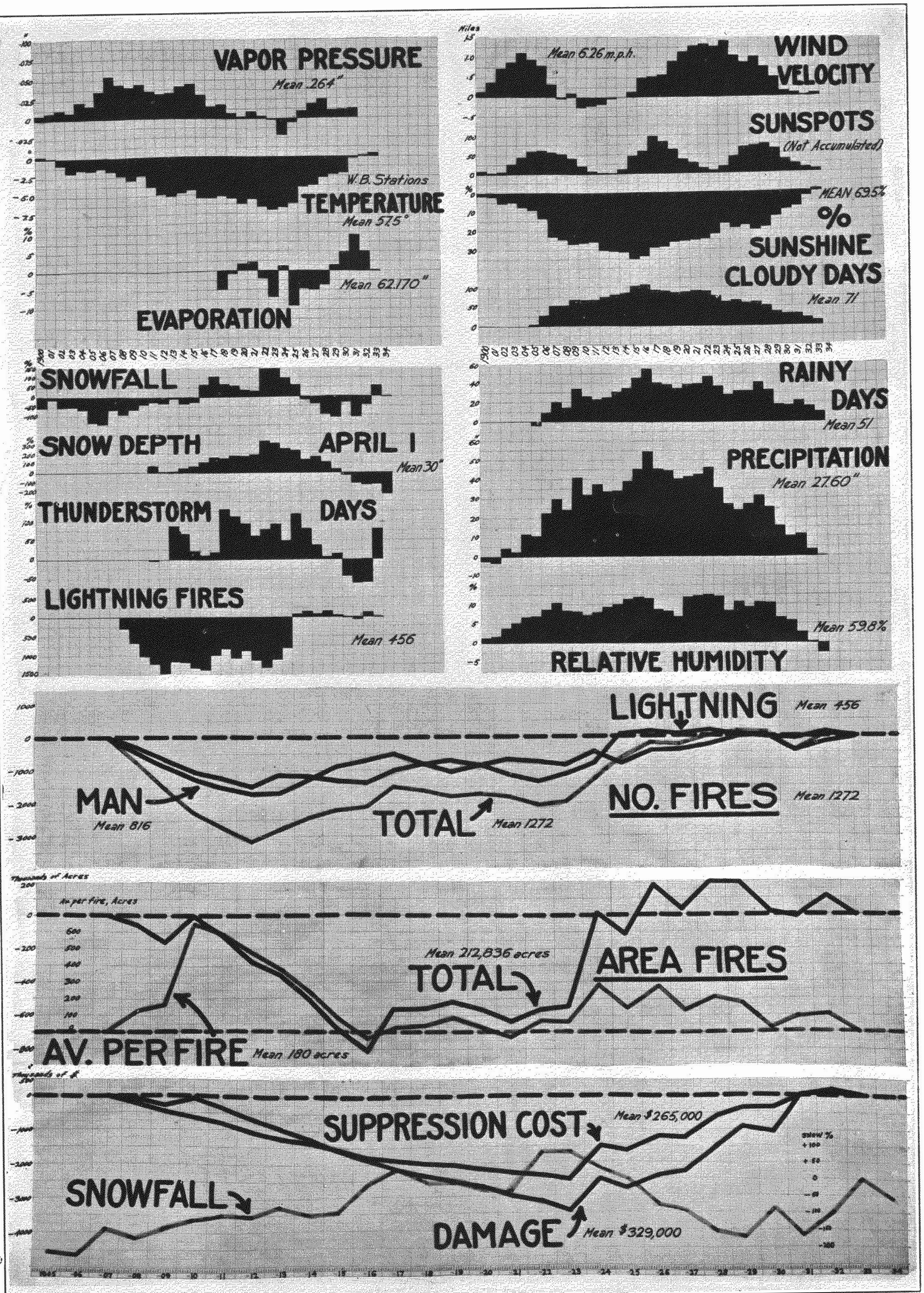
VAPOR PRESSURE
Mean .264"
W.B. Stations
TEMPERATURE
Mean 57.5°
Mean 62.170"
EVAPORATION
WIND VELOCITY
Mean 6.26 m.p.h.
SUNSPOTS
(Not Accumulated)
MEAN 69.5%
% SUNSHINE
CLOUDY DAYS
Mean 71
SNOWFALL
SNOW DEPTH
APRIL 1
Mean 30"
THUNDERSTORM
DAYS
LIGHTNING FIRES
Mean 456
RAINY DAYS
Mean 51
PRECIPITATION
Mean 27.60"
Mean 59.8%
RELATIVE HUMIDITY
LIGHTNING
Mean 456
MAN
Mean 816
TOTAL
Mean 1272
NO. FIRES
Mean 1272
Thousands of Acres
Av. per fire, Acres
Mean 212,836 acres
TOTAL
AREA FIRES
AV. PER FIRE
Mean 180 acres
Thousands of $
SUPPRESSION COST
Mean $265,000
SNOWFALL
DAMAGE
Mean $329,000
Snow %

FIGURE 5.

general agreement with portions, at least, of the summarized statements have any reality, it may be inferred that appreciably less favorable conditions are probable in the near future, with noticeable upward trends beginning about 1930, reaching a maximum about 1950 to 1955, with the earlier date most favored as the center of the period, and with more severe conditions centering around the year 2050.

In conclusion, it is believed that the approximately correct long-period weather and fire sequences have been shown for California, their connections have been demonstrated in a cumulative sense, and the opinions prevalent concerning future prospects have been given, not as forecasts, but as the current thought on the data by competent students. Whether the picture "before" will prove to resemble the picture "after", or be something unexpectedly different, is uncertain. All we can confidently assert is that long-period secular swings take place and modify conditions over extensive time periods and areas, but individual years or series of years, and individual places, are subject to shorter sequences which by "interferences" make prediction uncertain as to definite turning points, places or conditions during any particular season.

LITERATURE CITED

(1) Show and Kotok: Forest Fires in California, 1911–20; An Analytical Study. U.S.D.A. Circ. 243. 1923.
(2) Same: Weather Condition and Forest Fires in California. U.S.D.A. Circ. 354. 1925.
(3) Same: Cover Type and Fire Control in the National Forests of Northern California. U.S.D.A. Bull. 1495. 1929.
(4) A. A. Barnes: Rainfall in England: The True Long-Average as Deduced from Symmetry. Quar. Jnl. Roy. Met. Soc. v. 45, 1919, p. 209–32.
(5) C. F. Marvin: Concerning Normals, Secular Trends and Climatic Changes. Mo. Wea. Rev. August 1923, vol. 51 p. 383–90.
(6) A. Streiff: Mo. Wea. Rev. July 1926, vol. 54.
(7) D. Alter: Mo. Wea. Rev. December 1933, vol. 61.
(8) A. Streiff: Mo. Wea. Rev. October 1929, vol. 57.
(9) J. W. Shuman: Mo. Wea. Rev. March 1931, vol. 59.
(10) H. W. Clough: Mo. Wea. Rev. April 1933, vol. 61.
(11) Same: Bull. Am. Met. Soc. March 1934, vol. 62.

LONG-RANGE FORECASTS IN PUERTO RICO

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Reference to the tables of monthly surface-water temperatures of the Caribbean Sea and Florida Straits, 1920–32 emphasizes their close correlation with the surface air temperatures of windward coast stations in the area. A comparison of the annual temperatures for the period gives a positive coefficient of 0.88 for the San Juan-Caribbean Sea relation and 0.60 for Key West and the Straits. A comparable example is given by Pettersson (1), a coefficient of 0.86 being obtained for the air temperature of Madeira and the surface waters of the North Atlantic, 35 miles distant, based upon the years 1900–13. At San Juan the thermometric exposure is near the ocean at an elevation of 53 feet above sea level, the prevailing winds being easterly off the water. There occurs a lag in the yearly maximum temperature of both the air and water until the late summer or fall months. Another similarity is the maintenance of positive or negative trends with respect to the normal, for long periods. During the 35 years, 1899–1933, sequences of 14, 18, 19, 21, 22, 23 consecutive months appear in the mean monthly air temperature records, periods having the same temperature sign. This persistency is apparently due to a combination of factors, primarily the marine type of climate, and the position of the Island with respect to the North Atlantic high pressure area, with the continuity of circulation attendant upon it. The ocean currents, induced by the trades likewise play a part, the North Equatorial current dividing at the eastern end of the Antilles, forming the northerly current of the Bahamas and the southerly, flowing into the Caribbean. A correlation value of 0.82 was obtained for the temperature at San Juan and at Georgetown, Demerara, stations touching the north and south portions of the Equatorial current, respectively.

To trace, if practicable, the cause of the changes occurring at periodic intervals in the temperature trend with respect to the normal, comparison was made of the variations in wind direction between NE. and SE. at the station. This failed to indicate any definite influence on the corresponding temperatures, thus bearing out the statement of C. F. Brooks (2) that in the Tropics:

> The effect of change in wind velocity is most noticeable, while changes in direction are of little or no effect. When the trades are unusually strong for a period, the warm layer of surface water is driven forward and concentrated in the Equatorial current, where it forms a plus departure in temperature. The place of the warm surface sheet is taken by cooler subsurface water, making a minus departure.

C. E. P. Brooks (3) writing of the NE. and SE. trades, as these winds relate to the volume of the Gulf Stream, and later to the temperature of North Atlantic waters, has estimated the average rate of movement of the North Equatorial current at 17 miles per day, or the time required to flow between 16°N/23°W. and 16°N/60°W., a distance of 1,900 miles, at approximately 112 days. On this basis we may estimate the time to arrive at the eastern end of the Antilles as about 128 days, or 4 months. This being only the average rate, which would vary with the strength of the trades, a lowering of the figure by as much as 25 percent or a whole month would not be unusual in years when conditions favored. To obtain a value reflecting the monthly variation in the movement of the trades, mileage totals at the station of the NE., E. and SE. winds (constituting approximately 85 percent of the total movement) were used. These were then related to the variation in temperature of ensuing months, the results revealing that months of marked trades activity are generally followed by a decrease in temperature within 3 to 4 months. An excess of mileage did not in itself represent the control, unless the winds were of higher than normal velocity. In the summer and fall months, frequently, there occurred an excess mileage which only represented a steady trades circulation, to the exclusion of other directions, but with no exceptionally high velocities. At this season, too, the waters having been warmed to a greater depth, proportionately stronger winds become a requisite to induce a deep drift current, if temperature changes are to be effected. Such winds are generally lacking. The normal velocity of 15 miles per hour does not produce any marked disarrangement of the temperature gradient of the ocean (W. Ekman). Velocities in excess of this rate occur most frequently (80 percent of the total) in the months of November and December and January to April, a period of the year when the waters are warmed to the least depth. With this fact, it is not unexepcted to find a considerably higher correlation value resulting from the first and fourth quarter wind movement than in the second and third quarters (table 1). There is no indication, however, of a preliminary rise in temperature, mentioned by